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THE RELATION OF ANIMALS TO DISEASE

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To the student of science who in a retrospective mood surveys the records of the past, nothing is more striking than the failure of medicine to attain the advancement reached in other fields. Nowhere else can one find to-day among persons of education and intelligence such a mass of fraud and superstition, such a volume of ill-digested and undigested observations and conclusions as attach themselves to this all-important subject and hinder its proper advance and well-balanced development. And this unfortunate condition is clearly not due to any notable difference between the condition of medicine and that of other subjects in earlier days. Four hundred years ago astronomy, chemistry and zoology were as hopelessly entangled in the meshes of the fabulous as was medicine, but with the rise of science all have not advanced *pari passu.* Whatever the reasons for the difference, they stand on a very different basis to-day, and, unfortunately, that subject which is of the most vital importance for the human race has lagged in development far behind its foundation sciences.

It is not my intention this evening to endeavor to analyze the causes or explain the conditions which have led to this state of

affairs, but rather to discuss with you one phase of the great field covering the etiology of disease in which the scanty and inaccurate knowledge of the present day is especially apparent and in the development of which the microscope plays an essential part.

The consideration of the relation of various factors to the cause and spread of disease is of most recent origin. While popular superstition, more often false than correct, has recorded even in the most ancient history of medicine the source of various ailments, it is only within the last century that there has been any critical scientific study of the problem. Less than three score years cover the epoch-making investigations of Koch, Pasteur, and their coadjutors, which have laid the foundations and built up the already complex superstructure of bacteriology. By the efforts of these men the relations of minute plant germs, unicellular organisms which we call the bacteria, have been elucidated in great detail so as to justify a new theory of the origin of disease and a new and successful line of prophylaxis, or disease prevention.

Similar studies have not been made in the zoological field, but recent discoveries seem to indicate the existence of important relations heretofore unsuspected and emphasize the hopeful character of this new field for research. In order to secure a comprehensive survey and place new items in their approximate position it is fitting to review *in toto* the relations in which animals stand to disease, restricting the inquiry, however, for evident reasons, to such ailments as affect mankind.

The simplest relation is manifested when the animal becomes a carrier of disease germs. This is a purely mechanical function and such disease-producing organisms as may be adherent to the body of the carrier are transported unwittingly from one point to a new environment where similar chance causes them to be deposited. In this way such germs may be distributed widely from an originally small focus and may be brought into inappropriate and unfortunate relations to members of the human species. A very large number of isolated cases might be cited to demonstrate such mechanical transport by animal carriers. One of the best known is the transport of typhoid germs by means of flies. The bacilli which are found in excreta adhere to the feet and hairs of the fly walking over such material, only to be carried by the next flight of the insect to a dish of food or pan of milk left standing on a table in the

house or a bench at the door. In this new environment the germs may multiply and with it gain entrance to the new human host with disastrous results. Veeder has given a most vivid description of the unsanitary conditions which actually existed in our army camps in the Spanish-American War and which demonstrated on a large scale this mechanical transfer of typhoid germs. Moreover, it cannot be doubted that the bacilli actually are carried in such fashion, for in experiments reported in the Transactions of this Society, Maddox demonstrated that when such flies as have visited cultures of disease germs, walk over sterile gelatine plates they leave foci from which develop new colonies of bacteria of the specific sort. Experimental evidence is wanting which shall determine the actual extent of this infection, the distance to which such germs may be carried, and the length of time in which they remain alive and capable of producing an infection, as well as the other factors which control the importance of such mechanical transport. That it does play an important rôle can hardly be doubted, for to the numerous instances cited in 1899 in Nuttall's splendid monograph the intervening years have added both numbers and weight. To the instance already discussed where such transport was active must be added the passive transfer, as of typhoid germs in oysters, which is well established.

It should not be inferred from the preceding that only typhoid bacilli are transported actively or passively by animal carriers. The germs of cholera, anthrax, septicemia, pyemia, erysipelas, tuberculosis, and bubonic plague are said to have been transferred from one host to another in the same way. In some cases the evidence seems clear; in others a verdict of "not proven" must be entered; and yet the observations already on record call for a most thorough investigation and extended experimentation in order to reach a final conclusion as to how widely the mechanical transfer of disease-producing bacteria may extend. In many cases it is doubtless purely accidental—casual—as in the hospital cases infected by flies which Leidy records in Philadelphia, or by mosquitoes, as Giles notes in India. In such transfer of disease germs not only are flies the carriers, but also mosquitoes, bedbugs, fleas, and other blood-sucking insects, though to a less extent, if present evidence represents fairly the actual conditions. Probably such carriers of disease will be confined chiefly to the insects and the passive agents will be comparatively rare.

It has been observed, however, that such agents transmit disease germs in other manner than merely adherent to the external parts of the body. Many experiments have demonstrated that various bacilli may pass unharmed through the intestine of the fly and be distributed with the droppings of this insect to form centers of development wherever they chance to be deposited. More extended experimentation on this point is urgently needed, but one can hardly doubt that other insects, and perhaps many invertebrates, function in similar manner as distributors of infection. It should be noted that this manner of distribution is not confined to bacteria alone, although only scanty evidence is at hand concerning the mechanical transport of other forms. Thus Grassi found that flies sucked up with water eggs of various parasites, both tapeworms and round worms (*Taenia solium, Oxyuris, Trichuris*), and that these eggs were recovered unaltered from the dejections of the flies, while he also caught some flies with the alimentary canal full of these eggs. This is positive evidence that the fly is able to ingest solid bodies of some size through the sucking proboscis. At the same time he saw flies on his laboratory table feed on the eggs of *Trichuris,* and later found the eggs in droppings deposited in the kitchen in the story beneath, at a distance of ten meters from the place where the insects had been feeding. Such internal transportion evidently insures far greater freedom from damage and adverse conditions, as well as much wider dissemination, than were the spores or eggs merely adherent to external organs. Thus living cholera bacilli have been voided by a fly some days after the original contamination. In the course of this period of time the fly could have wandered to some distance from the place of infection.

Many investigations have shown, however, that small larvae or adult worms like trichinae were digested by the various animals to which they were fed, and have entirely disappeared in the course of a few hours. Such experiments have been made with frogs, salamanders, land and water beetles, maggots, and earthworms. Stiles tried some years ago a most interesting experiment which throws much light upon this subject. He placed fly maggots with some *Ascaris lumbricoides* and the latter were devoured, together with the eggs they contained. Not only the fly larvae, but also the pupae and the adult insects which developed from them were found to contain eggs of the *Ascaris*. As the experiment was carried out in

very warm weather the *Ascaris* eggs developed rapidly and were present in the insects in various stages. Evidently, then, the adult fly would serve as a disseminator of the parasite, and if the eggs obtained the proper stage of development the fly might infect man directly by depositing them on articles of food. It is known that certain seeds will develop only after having passed through the intestine of birds, and it may well be that a similar biological environment is necessary in the case of some disease germs. Some such condition would serve to explain the curious inability to infect experimentally by direct transfer where the disease is yet readily and abundantly transferred in nature. But the transferring insect would not be a mere mechanical carrier; it would constitute a necessary link in the life history. There are many such cases already known, but in most of them, at least, the disease-producing organism passes through some phase in its life history in the disseminating animal, which thus becomes an intermediate host, a necessary and not a casual element in the life cycle. Such forms are in no sense mechanical carriers, and it is evident that the limits between these two groups depend partly at least on the extent of our knowledge, since a more careful investigation may show that some instances of transfer which are regarded to-day as purely mechanical involve in reality more complicated relations. It is of the greatest importance that these relations be definitely established, for on them depends the introduction of a rational hygiene, and yet even the merely mechanical function of the fly in the dissemination of disease calls for strict measures to abate this nuisance. Anyone may convince himself, even by superficial observation, that both individuals and communities through carelessness allow and produce conditions which breed enormous numbers of unnecessary flies. Rational hygiene calls for the removal of these conditions and the extermination of flies. Fortunately, to-day one does not need to emphasize in civilized countries the undesirable character of bedbugs, cockroaches and other vermin which doubtless play a part in the mechanical transfer of disease germs, and probably are also associated more intimately with certain maladies, as will appear in the succeeding paragraphs.

Animals are also breeders of disease as well as carriers in a mechanical sense; and the part they play as breeders of disease may be either purely facultative, or, on the other hand, essential to the

spread of the malady. Regarding the facultative rôle of animals in breeding disease, comparatively little exact evidence is at hand. It is somewhat generally maintained that various human diseases afflict certain animals, and the domesticated animals which stand in such close relations to man have been those against which up to the present time such charges have been most frequently made. The evidence is scanty, inconclusive and in some cases of no value at all; and yet one cannot doubt that some of the germs which infect man do live also in other animals. Even among the higher animal parasites but few species are confined exclusively to the human host, and some, like *Ascaris lumbricoides* or *Trichinella,* may occur in a wide range of hosts. It is an important duty for the students of comparative medicine to determine to what extent disease-producing organisms may parasitize other hosts than man, for in this possibility lies the secret of the transmission and appearance at isolated points of new disease foci in some of the cases hitherto unexplained. It should be noted distinctly that when animals are facultative breeders of disease they merely afford a suitable ground in which the disease germs may multiply and an agency by which they may be distributed. Such animals are not in any way necessary to the existence or development of the germs; they only serve to increase the percentage of infection or the area of distribution characteristic of the disease. It is thus an important but not an essential rôle. Without question it plays some part, but how weighty its influence may be or in just what directions it may be exerted we are at present entirely unable to measure or estimate. This is unquestionably a most important and fruitful field for investigation.

In another sense, also, animals are breeders of disease, as when some part of the life history of the disease-producing germs is passed within the animal before that stage is reached in which the germ may infect a new human host. Here the relation is an essential one, and the intermediate host is a *condicio sine qua non* for the further spread of the disease. Such a relation is very widely known among animal parasites. The embryo of the sheep liver-fluke, for instance, *must* undergo certain phases of development and reproduction within a snail before it reaches that form which can re-infect the sheep. The embryo of the unarmed human tapeworm *must* enter another host, the beef, and grow to a bladder worm, and this alone can produce an adult tapeworm in the human alimentary canal.

The embryonic roundworms in the human blood *must* be drawn into the stomach of the mosquito, wander out into the thoracic muscles and grow to a definite stage of development before they can again enter the human host and become sexually mature adults which produce the blood-inhabiting embryos. In the case of malaria, the germs of *Plasmodium malariae must* be drawn up into the stomach of the *Anopheles* mosquito, and within the body of this new host undergo a complicated series of changes before the new generation of spores is ready to be injected with the saliva into the blood of a man in whom these germs produce a new case of malaria. Not only is the intervention of a biting insect essential, and we know none other than the *Anopheles* mosquito which can ' fill the bill,'—if you will allow the apparently appropriate expression,—but it is equally true that the organism must pass through the complicated phases of its life history in the mosquito before the latter can infect. This is possibly still clearer in the case of yellow fever, even though the specific organism which is the cause of the disease remains as yet unknown. The mosquito which can transmit this disease is also a specific type, *Stegomyia fasciata,* designated often as the yellow fever mosquito. It acquires the power to transmit the disease by feeding on the blood of a yellow fever patient, but it can infect a non-immune person only after a period of ten to twelve days. Before that time the bite of this infected mosquito is harmless, and this condition can be explained only on the basis that the organism of the disease passes through certain stages in its development within the mosquito as a necessary preliminary to reaching the condition in which it is able to reenter the human frame and infect such persons as are susceptible. Until this period in the life history of the disease germ has been completed, the mosquito remains innocuous. On no other basis than this can the time interval be explained during which the mosquito does not transmit the disease, while after that limit has been passed the insect remains capable of infecting man up to the end of its existence, or at least for more than two months.

The cases given illustrate in a representative way the phenomenon of alternation of hosts as it occurs often in the life history of parasites belonging to different groups of animals. In some cases the stay in the intermediate host is merely the occasion for growth and metamorphosis as with the blood filariae in the mosquito or the

tapeworm embryo in the beef. But in other cases there is a reproductive period in this intermediate host, so that the change of hosts is associated also with alternation of generations or metagenesis. By means of this new generation the number of spores, eggs, embryos, or other infecting units is markedly increased and the complicated and dangerous life cycle of the parasite finds its compensating factor in multiplied numbers. Among the arthropod parasites alternation of generations and change of hosts is rare; but among the parasitic worms both phenomena occur frequently. Thus all endo-parasitic flukes, so far as the life history is known, manifest alternation of hosts and of generations; direct development has not yet been shown to occur in any tapeworm, although there is only rarely any new reproductive period in the life cycle. The roundworms, or Nematoda, display every grade from the most extreme simplicity and directness of development and transfer, to such complicated changes and wanderings as have even yet eluded the scrutiny of the closest investigator or when announced have aroused the ridicule of the scientific world on account of their improbability. As an excellent instance of these complicated relations may be cited the life history of the European hookworm, published by Looss, little more than a year ago. Looss has followed the migration step by step from the time the minute larvae penetrate the hair follicles of the skin, enter a lymph space or a capillary, to be carried by the current through the vessels ultimately into the right side of the heart and from there into the lungs, where they desert the vascular system and migrate into the air cells, and then wandering outward along bronchioles, bronchi, and trachea pass over the dorsal margin of the larynx and into the oesophagus, from which their pathway lies directly back through the alimentary canal to their final location in the small intestine. This migration requires ten weeks, during which time they pass through moults and grow in size, attaining the adult form and sexual maturity only after arrival at the end of the journey. Here the entire life cycle is passed in a single host, but its different phases are associated with various organs. In still other cases among the Nematoda a free-living generation alternates with the parasitic generation, instead of two, which are found in different hosts.

Concerning conditions among the Protozoa, there is less definite knowledge of the life history than among the higher groups, but

instances of all the conditions cited for the worms may also be found here. Some species undergo direct development, others make a single or even a double change of hosts, and in some two generations of different type alternate in the complete life cycle of the organism. Thus the amoeba of tropical dysentery (*Entamoeba histolytica*) seems to develop directly; the blood amoeba of malaria (*Plasmodium malariae*) goes through an asexual reproductive cycle in man, and another, the sexual cycle, in the mosquito. In this case we know that the mosquito is not the mere mechanical carrier of the disease germ, but that it is a necessary link in the life history, a breeder as well as a transmitter of disease. Regarding the rôle of the cattle tick in Texas fever, it may be inferred with great probability that it plays a similar part, even though the history of the parasite within the tick has not yet been worked out. In other diseases, such as sleeping sickness, where the parasite, a flagellate protozoan known as a trypanosome, is transmitted by a biting fly, familiarly called the tse-tse fly, there is less evidence on which to base a conclusion. The tse-tse fly may be purely mechanical in its intervention; it seems more probable, however, that it plays a more intimate part. The instance shows very clearly, however, that until the life history has been elucidated, it is impossible to determine the relative importance of any element in the series, or intelligently to combat the disease which evidently should be attacked at its weakest point. This factor will be considered more in detail later on.

But animals also stand in a causal relation to disease; certain forms are definitely shown to be producers of disease and in this aspect demand especial consideration. This fact has been generally recognized in the case of a few parasites from the earliest days of medical history. The fiery serpent of the wilderness was no doubt the guinea worm, of which the most ancient medical writings make note; and in this instance not only the cause of the malady, but also the general mode of infection through drinking water, and the method of cure, the removal of the worm, were known to the Egyptian as well as to the Greek physicians. But such instances are rare. Regarding merely even the larger, more conspicuous parasites of man the wildest ideas were formerly current as to their origin and their effect on the system. Thus tapeworms were supposed to originate from thickened mucus, or from

an abnormal condition of the alimentary canal; and various animal parasites were from time to time regarded as the causes of cholera, typhoid, and other similar diseases. Such views as these prevailed generally even less than a century ago, and it is not strange if in consequence of more accurate knowledge on these points and of the rejection of such wild theories of disease, the pendulum has swung to the opposite extreme and animal parasites have come to be considered of insignificant importance in the etiology of disease.

Two factors tended to strengthen this view and further belittle the possible rôle of animals as disease producers. In the first place, with the possible exception of malaria, no animal organism was known to be the cause of any general disease; and while the animal nature of the *Plasmodium malariae* was never doubted in any considerable circle, the case stood so evidently isolated that it emphasized all the more its own peculiarity. But even more powerful than this was the rise of a new science, bacteriology. Certain minute plant germs had been found to be the cause of decay, why not of disease? In response to the needs of the case there arose a new technique for handling and studying these forms, a rigorously analyzed series of conditions for determining their possible relation to disease; and a new field of science was organized. Discoveries followed one another with marvelous rapidity and every year saw the elucidation of the cause of new maladies. It seemed as if the secrets of disease had been laid bare; men had traced the causes to bacteria in many cases with such success that they continued to follow the same line in other yet unexplained diseases, confident that there was only some minor defect in technique which would soon be overcome and the solution obtained. Indeed, the very name "disease germs" was regarded as equivalent to bacteria. There is no doubt that success in this direction served to draw attention away from the signs which presented themselves in other fields and particularly to minimize the animal organism as a causal factor in disease. Recent discoveries of great import which have crowded hard upon each other, are disclosing here a new field and stimulating the investigation of neglected territory. Let us now examine *seriatim* the different groups of animals to secure a clear idea of the rôle played by each in the production of disease.

The disease-producing organism works slowly, insidiously, saps the vigor of the infected individual without consuming the substance

so as to destroy life by immediate destruction of the body. It is clearly not carnivorous, but rather parasitic in habit; consequently among the vertebrates, as well as among the largest and most powerful invertebrates, one could not expect to find such forms. These largest species might be carriers of disease or even breeders of sickness, but they could not constitute the immediate cause of the malady. It may be interesting to note in passing an apparent exception to this rule. The lamprey attaches itself to other fish and is directly the cause of the ulcers on the skin which mark the points of the lamprey's fixation, and of the anemia which follows its blood-sucking and often induces the death of its host. But this instance stands alone.

In the great majority of cases the disease producers are small organisms, or at least gain their entrance into the body of the host in a form so minute as to defy detection. The arthropods furnish many carriers of disease and breeders also, as the extended references already made to these forms suffice to show. The more or less perfectly acquired external parasitism of these forms is admirably adapted to these functions, but such animals are not the immediate cause of disease, and when sickness follows a bite of a fly, a spider, or a tick, the effect is more probably due secondarily to the bite and primarily to some other organisms introduced thereby.

In the case of the parasitic worms the conditions are decidedly changed. Here are species which parasitize within the body, often suck the blood of the host, lacerate delicate mucous membranes, induce internal hemorrhages, in some instances feed upon the cells of the tissues, and destroy important organs, or grow to such a size as to encroach upon normal structures and functions. In addition to these anatomical interferences, some of the parasitic worms are known to produce waste matter in their own biological processes, toxins, which act deleteriously upon the host organism and evoke abnormal and serious symptoms in it. Thus Vaullegeard has isolated experimentally from tapeworms two chemical substances which act upon the blood and nerve and when injected into experimental animals subcutaneously produce the epileptic symptoms that characterize severe cases of tapeworm infection. Then the physician speaks of a "bothriocephalus anemia" recognizing a definite group of symptoms, a distinct disease produced by the parasitism in man of the broad fish tapeworm (*Dibothriocephalus latus*). Here the

animal is the immediate cause of the disease and the removal of the tapeworm is followed at once by the disappearance of the undesirable symptoms.

While there are some animal parasites which are believed to be harmless, or, better expressed, do not do any damage to the human system, so far as present knowledge extends, yet the studies of recent years have furnished constantly increasing evidence of the pathogenic rôle of these organisms. They do damage indirectly by irritating the delicate mucous membranes and by lacerating them, thus giving access to the omnipresent bacteria, a danger which has been greatly underrated. But they are also the direct cause of disease which in consequence of their part in its production the physician names after the species of parasite, as trichinosis, uncinariasis, hydatid disease, etc. Note further that they are not factors of trivial importance in general hygiene or of little bearing upon the welfare of a nation as a whole, and that a large percentage of such diseases can be treated only by preventive medicine. Thus trichinosis, which is caused by eating pork containing living trichinae (*Trichinella spiralis*), is accompanied by a high mortality and even yet is a serious disease in northern Germany; its prophylaxis is, however, exceedingly simple and no one who is careful to avoid under-done pork will ever suffer from its attacks. Again, hookworm disease, or uncinariasis, has been shown by the researches of Stiles and others to be very abundant in certain parts of our southern states. The presence in the alimentary canal of myriads of minute hemorrhages caused by the action of these worms, results in a chronic anemia which prevents the attainment of physical or mental development, stunting the individual and leaving him on arrival at years of maturity little more than a child in body and in intellect. Much of the degeneracy of the poor white trash of the South is due not to inherited defects or to family shortcomings so much as to the presence of this parasite which from early childhood has continually sapped the vitality of the individual. It needs no extended argument to demonstrate the sociological effect of the recognition and removal of this one cause of disease. Nor will anyone doubt the desirability—yes, the necessity—for a careful investigation into the life history and effects of these parasites. For from the life cycle is to be obtained the clue to the means of attack, to the weak spot in the armor of the disease, on which its

ultimate destruction depends; and everyone recognizes as the ultimate goal of medicine as a science, the eradication of such diseases, that the physical man may move forward toward the possibilities in perfect development with which he is endowed.

That which I have outlined has been known in part for many decades, even though the investigations of recent years have contributed much towards a clearer comprehension of the question. Among the Protozoa, however, the last few years, and even months, have brought discoveries of the most startling character regarding their relation to disease. It was in 1880 that Laveran first discovered the amoeboid parasite in the red blood cells now universally recognized as the cause of malaria, and not until 1899 was its life history clearly outlined, while even yet some minor details of the picture are lacking. Since the opening of the new century there has come the demonstration of the cause of sleeping sickness, a terrible disease of tropical Africa, in a flagellate protozoon (*Trypanosoma*), other species of which in the blood of various domestic animals have been shown to give rise to widespread and fatal epidemics in other countries; the parasite of smallpox has been found to belong to this same group and its life history has been determined partly at least. The disease known as kala-azar, dum-dum fever, or splenomegaly, a fatal malaria-like malady of India and Africa, has been traced to another protozoan parasite; in yellow fever it seems probable that such organisms are the exciting cause; in various other diseases they have been seen, even though in some cases subsequent investigation has failed to demonstrate the parasites and confirm the reports; and finally within this year accounts by well-known German investigators proclaim the discovery of the cause of syphilis in a hitherto undiscovered protozoon of the order of flagellates. In all of these maladies the bacteriologists have been searching with great care for the etiological factors, but their efforts have been fruitless. It is apparent that the new field will demand its own technique, and until that has been developed and the proper standards of judgment formulated, much work will necessarily go to waste and many errors be committed.

These organisms, the unicellular animals, are distinctly analogous to the unicellular plants, among which the bacteria stand as the characteristic disease producers. Indeed, the recent studies have shown that one genus, *Spirochaeta,* long known and hitherto clas-

sified among the bacteria, is probably not such, but rather a flagellate protozoon. And possibly other genera of Protozoa are also wrongfully assigned to the bacteria. On the other hand, zoologists have long recognized certain forms of Protozoa as pathogenic, producing disease among the various other animals, and this is at least an indication of their filling a similar rôle in the human body.

In consideration of these facts, it is not unreasonable to believe that we stand now at the opening of a new field which is to make of itself in the future what bacteriology has made in the last half century. There is need of a Pasteur, a Koch and their confrères to lay the foundations strongly and to analyze with equal sharpness the relation of these animal micro-organisms to disease. Even now the new field has been recognized and the London School of Tropical Medicine has appointed this year an investigator in protozoology—however unfortunate the form of the term may be.

There are already listed more than thirty of the Protozoa which parasitize the human body. Regarding many of them our knowledge is exceedingly scanty, but of others it may be affirmed definitely that they are the cause of diseases which rank among the most dangerous of those to which man is subject. Among these forms I have included only those that are distinctly recognizable in structure as Protozoa, though their life histories and exact relationships are yet unexplained; but beyond these limits lies a vast horde of unidentified structures, interpreted by some observers as parasitic Protozoa, but regarded by others as parasitic fungi, and by still others as products of cellular degeneration or other pathological changes. Such are the cancer parasites of several investigators, the organisms of leukemia, scarlet fever, and other diseases. No doubt some of these will be shown by further research to be in fact independent organisms of parasitic habit and the cause of disease, and it seems probable that many of them will fall within the group of Protozoa, the unicellular animals. Here has been opened up a new field in which the microscope is the essential instrument of investigation. All the work to be done in it depends upon this instrument, without which the very existence of these organisms would have remained unsuspected. Following close upon the wonderful discoveries of the histologist, the pathologist, the bacteriologist, and the clinician, these studies furnish new evidence of the supreme importance of the microscope in the development of scientific medicine, in the attainment and preservation of the health of mankind.

There is left but a paragraph in which to mention another aspect of the subject of this address. Even under the narrow limits of the topic—the relations of animals to disease—there is one phase which in justice to them should not be entirely omitted. Animals stand also distinctly as preventers of disease; and this in the first place as destroyers of disease germs. Among the Protozoa, which have already been exploited as the producers of disease, are found also the organisms which play the most important part in the purification of sewage-contaminated streams by consuming the bacteria. These forms are specifically ciliates, of which the common slipper-animalcule (*Paramecium*) may serve as a typical form; they abound in all waters, especially in those containing decaying matter, and devour countless numbers of bacteria. Through their activity it becomes possible for one city to drink the diluted sewage of another city higher up on the watershed without losing all its citizens from intestinal diseases.

Modern science has also made use of animals in combating disease; as producers of antidotes, either in the form of cowpox or vaccine, or in the rôle of test animals and of serum producers manufacturing antitoxins of various sorts; many animals discharge in this way a most essential function in modern life. But the discussion of this phase lies beyond the demands of the present occasion.

In closing, let me call your attention to the bearing these studies on the relations of animals to disease have on the science of medicine. Any rational method of cure depends upon the distinct recognition of the cause of the malady. Any other basis gives unlimited opportunity for chicanery and fraud and for the despoilation of the people in the name of medicine so general at the present time. But more than that, preventive medicine is to be the ultimate product of the scientific studies of to-day; no one can question that it is a far higher and more desirable type than curative medicine which now generally seeks to remedy the ills begotten through ignorance. The loss to the world by preventable disease is enormous; it includes many of the wise and the good, of the best products of human evolution during past centuries, for no selective action determines that the worse element shall be wiped out. In truth, the delicate nervous balance of the highly developed human organism seems to be more easily disturbed by the attacks of disease than the grosser clay in which all energy has gone to physical development. To stop

this loss is the greatest problem of the future in medicine. And the very first step in this problem is the positive determination of causes of disease and of the means by which they are transmitted and multiplied. Without this knowledge rational prophylaxis is impossible; before it and the results of associated investigations of purely scientific character quackery must yield as the night before the day, schools and theories will disappear, and medicine will take its rightful place among the sciences.